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Research Article

Agro-Economic Productivity of Different Transplant *Aman* Rice – *Rabi* Crop – Dry Direct Seeded *Boro* Rice Patterns in Old Brahmaputra Floodplain Agroecological Zone of Bangladesh

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ABSTRACT

Dry direct seeding is an alternative rice establishment system that saves irrigation water, reduces greenhouse gas emission and increases farm income. An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the agro-economic performance of different transplanted (T.) *aman* rice - *Rabi* crops – dry direct seeded (DDS) *boro* rice patterns. Nine cropping patterns, namely, i. T. *aman* rice - Mustard - DDS *boro* rice, ii. T. *aman* rice - Potato - DDS *boro* rice, iii. T. *aman* rice - Field pea - DDS *boro* rice, iv. T. *aman* rice - French bean - DDS *boro* rice, v. T. *aman* rice - Spinach - DDS *boro* rice, vi. T. *aman* rice - Garden pea - DDS *boro* rice, vii. T. *aman* rice - Tomato - DDS *boro* rice, viii. T. *aman* rice - Broccoli - DDS *boro* rice and ix. T. *aman* rice - Cabbage - DDS *boro* rice was considered in the study using a randomized complete block design with three replications. The results revealed that the yield and related attributes of the DDS *boro* rice did not vary significantly in different cropping patterns. The rice equivalent yield (REY) of *rabi* crops was the highest for cabbage (10.37 t ha^{-1}) and the lowest for garden pea (4.24 t ha^{-1}). The system yield (SY) was the highest for T. *aman* rice - Cabbage - DDS *boro* rice pattern (19.69 t ha^{-1}). The second highest SY value was found with T. *aman* rice - Tomato - DDS *boro* rice pattern (16.30 t ha^{-1}) which was similar with T. *aman* rice - Potato - DDS *boro* rice pattern (16.17 t ha^{-1}) and T. *aman* rice - Mustard - DDS *boro* rice pattern (14.88 t ha^{-1}). The benefit cost ratio (BCR) was the highest (1.71) with T. *aman* rice - Cabbage - DDS *boro* rice pattern and the lowest (1.46) with T. *aman* rice - Field pea - DDS *boro* rice pattern. The result concludes that there would be no yield penalty of dry direct seeded *boro* rice under different T. *aman* rice - *Rabi* crops - DDS *boro* rice patterns. However, highest crop productivity and economic return could be achieved by using cabbage, tomato, potato and mustard as *rabi* crop in the T. *aman* rice – *Rabi* crops - DDS *boro* rice pattern.

Introduction

Rice (*Oryza sativa L.*) contributes about 97% of the food grains consumed in Bangladesh. The production of *aman* rice, *Boro* rice and *aus* rice in this country are 14.44, 20.88 and 3.28 million tons from 5.62, 4.87 and 1.30 million hectares in 2020-21, respectively (AIS, 2022). Thus, boro is the major contributor to the total rice production of the country. *Boro* rice is cultivated by transplanting of seedling in puddle land under full irrigated environment. About 14 million liters of water is required to produce rice in one hectare of land in the traditional system and the requirement of irrigation water can be reduced by 50-60% using dry direct seeding (DDS) system (Rahman, 2019).

T. *aman* rice – Fallow - T. *boro* rice is the major cropping pattern occupying 26.92% of the net cropped area of 8.56 million hectares (Rahman, 2018). Very recently farmers are growing mustard and potato in rabi season under T. *aman* rice – *Rabi* crop - T. *boro* rice pattren to increase cropping intensity and crop productivity. However, *boro* rice production using the conventional puddle transplanting system requires huge irrigation water for seedling raising, puddling and transplanting. The conventional T. *boro* rice could be easily replaced by DDS *boro* rice as the latter is found more water efficient and profitable (Rahman and Masood, 2014). Therefore T. *aman* rice - *Rabi* crop - DDS *boro* rice pattern is the best alternative to the T. *aman* rice -*Rabi* crop - T. *boro* rice pattern.

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Many short duration *rabi* crop such as mustard, potato, field pea, garden pea, tomato, cabbage, broccoli, carrot and spinach can be cultivated successfully in rabi season between the T. aman rice and boro rice under T. *aman* rice - *Rabi* crop - *Boro* rice pattern. For timely sowing of rabi crops, short duration *aman* rice varieties are cultivated in the T.*aman* rice - *Rabi* crop - T. *boro* rice pattern. The *boro* rice is generally cultivated after harvest of *rabi* crop in the last week of January to middle of February. The optimum time of sowing of the popular *boro* rice variety BRRI dhan28 is last week of January to middle of February. The life durations of some *rabi* crops are longer and that may delay the planting time of succeeding *boro* rice in T. *aman* rice - *Rabi* crop - *Boro* rice pattern (Rahman, 2021).

Nonetheless, the effect of *rabi* crops on the yield performance of the succeeding dry direct seeded *boro* rice needs to be evaluated for selecting the suitable DDS rice-based cropping pattern. Moreover, total productivity and profitability of a cropping pattern should also be assessed for its sustainability. Therefore, selection of a *rabi* crop for fitting into the T. *aman* rice - *Rabi* crop - DDS *boro* rice pattern should be explored for increasing cropping intensity, productivity and farm income. The present study was therefore undertaken with a view to examining the effect of *rabi* crops on the yield performance of *boro* rice and also to evaluate the agro-economic performance of different T. *aman* rice - *Rabi* crops - DDS *boro* rice patterns in Old Brahmaputra Floodplain Agroecological zone (AEZ 9) of Bangladesh.

Materials and Methods

Description of the study site

The experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh (24°75′ N latitude, 90°50′ E longitude and at an altitude of 18 m). The experimental site belongs to the Sonatala series of Old Brahmaputra Floodplain Agro ecological Zone (AEZ 9) having non-calcareous dark grey floodplain soils. The land was medium high with moderate drainage facilities. The soil was silt loam in texture with particle and bulk density values of 2.60 g cc^{-1} and 1.35 g cc^{-1}, respectively. The pH value of soil was 6.5. Soil contained 1.78% organic matter, 0.14% total N, 1.98 µ g^{-1} available P, 0.10 meq 100 g^{-1} exchangeable K and 4.56 µg g^{-1} available S. The experimental area is under the sub-tropical climate which is characterized by its heavy rainfall during *Kharif* season (April to September) and scanty rainfall during *Rabi* season (October to March). The overall weather conditions of the experimental site have been given in Table 1.

Table 1. Monthly average air temperature, relative humidity, total rainfall and average sunshine hours during the period from December 2017 to May 2018 of the study site

Month and year	Air Temperature (^{0}C)			Rainfall (mm)	Relative humidity (%)	Sunshine (hrs)
	Maximum	Minimum	Average			
July 2018	32.4	26.8	29.6	299.6	85.4	122
August 2018	32.7	26.9	29.8	214.7	84	163.5
September 2018	32.7	26.0	29.4	143.9	84.4	145.7
October 2018	30.9	22.6	26.8	95.1	84.9	190.4
November 2018	29.3	17.4	23.4	36.2	81.7	228.9
December 2018	26.0	13.5	19.8	17.7	80.2	201.3
January 2019	26.3	12.2	19.3	0.0	84.35	227.2
February 2019	27.0	15.5	21.3	1.2	83.00	164.8
March 2019	29.8	17.7	23.8	1.9	73.19	208.2
April 2019	31.7	22.3	27.0	2.2	77.67	193.5
May 2019	32.5	23.4	28.0	11.1	81.26	179.8
June 2019	31.1	25.3	28.2	695.2	87.45	95.2

Source: Department of Irrigation and water management, BAU, Mymensingh

Experimental treatments and design

Nine *rabi* crops were included in the experiment to form nine different T. *aman* rice -*rabi* crop - DDS *boro* rice cropping patterns namely, i. T. *aman* rice - Mustard - DDS *boro* rice, ii. T. *aman* rice - Potato - DDS *boro* rice, iii. T. *aman* rice - Field pea - DDS *boro* rice, iv. T. *aman* rice - French bean - DDS *boro* rice, v. T. *aman* rice - Spinach - DDS *boro* rice, vi. T. *aman* rice - Garden pea - DDS *boro* rice, vii. T. *aman* rice - Tomato - DDS *boro* rice, viii. T. *aman* rice - Broccoli - DDS *boro* rice and ix. T. *aman* rice - Cabbage - DDS *boro* rice. The experiment was laid out in a randomized complete block design (RCBD) with three replications. The size of each unit plot was 15 m^2 (5 m x 3 m). The spaces between blocks and plots were 1.0 m and 1.0 m, respectively.

Description of the test crops

Rice varieties Binadhan-7 and BRRI dhan28 were used for cultivation in *aman* season and *boro* season, respectively. The growth duration (seed to seed) for

Binadhan-7 is about 110 days while that for BRRI dhan28 is 140 days. The name of the varieties of the *rabi* crops, their field durations, seed rates and plant spacing are given in Table 2.

Table 2. Name of variety, field duration, seed rate and planting spacing of *rabi* crops

Rabi crops	Name of variety	Field duration (days)	Seed rate (kg ha^{-1})	Planting spacing
Mustard	BARI Sharisha-14	75-80	8.0	30 cm (L-L)
Potato	BARI Alu-25, Asterix	90-95	2000.0	60 cm x 25 cm
Field pea	BARI Motor-1	95-100	25.0	30 cm (L-L)
French bean	BARI Jharsheem-1	80-90	120.0	30 cm x 15 cm
Spinach	BARI-Palonshak-1	140-150	20.0	30 cm (L-L)
Garden pea	BARI Motorshuti-1	70-75	25.0	30 cm x 15 cm
Tomato	Binatomato-7	90-95	0.20	60 cm x 40 cm
Broccoli	BARI Broccoli-1	135-140	1.0	60 cm x 45 cm
Cabbage	Atlas-70	70-75	0.50	60 cm x 45 cm

L-L = line to line distance

Crop management

T. aman rice

The experiment used T. *aman* rice - *rabi* crop - DDS *boro* rice cropping pattern. The *aman* rice variety Binadhan-7 was transplanted on 30 July 2018 with 25-day old seedlings in the well puddled land at 25 cm × 15 cm spacing allocating 3 seedlings hill^{-1}. Fertilizer nutrients N, P, K, S, and Zn were applied at the rate of 90, 10, 35, 12 and 1.0 kg ha^{-1} in the form of urea, TSP, MoP, Gypsum and Zinc sulphate respectively (BARC, 2018). All the fertilizers except urea were applied during final land preparation, while urea was applied in three equal installments at 15, 25 and 35 days after transplanting. Pre-emergence herbicide pretilachlor (Rifit) was applied at 3 days of transplanting. Early post emergence herbicide Pyrazosulfuran ethyl (Pyzero) was applied at 15 days after transplanting to control tender weeds. The crop was harvested at full maturity.

Rabi crops

After harvest of *aman* rice, there occurred an unexpected rainfall that delayed the land preparation for *rabi* crops. However, seeds of mustard, potato, spinach, field pea, French bean and garden pea and seedlings of broccoli, cabbage, tomato were planted on 22 November 2018 at seed rates and spacing following BARI (2017) recommendation (Table 2). Fertilizers were applied at recommended rates (Table 3) following the standard protocol (BARC, 2018). Intercultural operations were done for each rabi crop as and when needed. The crops were harvested at proper stage of maturity of the crops from the whole plot.

Table 3. Rates of different fertilizer elements (kg ha^{-1}) used in the rabi crops

Rabi crop	N	P	K	S	Zn	Cow dung
Mustard	120	36	43	26	2	10000
Potato	92	44	40	16	4	10000
Field pea	25	50	43	8	4	10000
French bean	92	40	75	8	2	10000
Spinach	23	18	20	5	2	10000
Tomato	230	90	110	20	2	10000
Broccoli	115	30	100	16	2	10000
Garden pea	46	50	43	8	2	10000
Cabbage	140	30	60	8	2	10000

DDS boro rice

Boro rice was cultivated after harvest of each *rabi* crop. Primed seed of rice variety BRRI dhan28 was sown by hand in dry cultivated well prepared land in the respective experimental plots maintaining 25 cm × 15 cm spacing allocating 4 seeds hill^{-1} and at a depth of 4-5 cm. Seeds were primed by soaking in water for 24 hours followed by 30 hours incubation. Seed sowing was done on 17 January 2019 in spinach plot, 31 January 2019 in potato plot, 12 February 2019 on broccoli and cabbage plot, 22 February 2019 in mustard plot, and 14 March 2019 in field pea, French bean, garden pea and tomato plots. The land was fertilized with N, P, K, S and Zn at the rate of 150, 20, 65, 18 and 1.3 kg ha^{-1} in the form of urea, Triple super phosphate, Muriate of potash, gypsum and zinc sulphate, respectively. The whole amount of fertilizer except urea was applied at the time of final land preparation. Urea was applied in three equal splits at 25, 45 and 65 days after sowing (DAS). The crop was harvested at full maturity when about 80% of the grains became golden yellow in color.

Harvesting and processing

For yield measurement of *aman* rice, the crop was harvested on 26 October 2018 from the randomly selected three spots of 10 m × 10 m area from the whole field. In case of *rabi* crops, spinach and potato were harvested on 13 January and 21 January 2019, respectively. Cabbage and Broccoli were harvested on 11 February 2019 while Mustard and tomato were harvested on 19 February and 3 March 2019, respectively. Field pea, French bean and Garden pea were harvested on 11 March 2019. For *boro* rice, the crop was harvested at different dates depending on the sowing dates in the respective rabi crop plots. Harvesting was done on 3 June 2019 for spinach and potato plots, on 11 June 2019 for cabbage and broccoli plots, on 24 June 2019 for garden pea and tomato plots and on 1 July 2019 for field pea, mustard and French bean plots. For *boro* rice, the central 3 m × 5 m area of each plot was harvested to record the grain and straw yields. Grain and straw were sun dried and then grain and straw yields were expressed in t ha^{-1}.

Data recording and economic analysis

Data on yield and related attributes of boro rice was recording from randomly selected five hills from each plot. Yield of each crop in the patterns were recorded and the system yield was calculated by adding the yield of all the crops in the pattern. Rice equivalent yield (REY) of each rabi crop was calculated using the formula (Kumar *et al*., 2019)

$$REY \text{ (of crop X)} = Y_x \times (P_x / P_r)$$

Where, Y_x = yield of crop X (t ha^{-1}), P_x = unit price of crop X, and P_r = unit price of rice.

Cost of production for each crop in a pattern was calculated and the total cost of production of a pattern was recorded. Gross return, net return and benefit cost ratio (BCR) of each pattern were also recorded. Net return or profit was calculated by subtracting production cost from the gross value of the produce, including by-product value. Prices used for harvest products were average prices observed during the experimental period in local market. The benefit: cost ratio (BCR) was calculated by dividing the net return by the production cost for various systems.

Statistical analysis

The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. Data were analyzed using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and mean differences were adjudged by Duncan's Multiple Range Test.

Results and Discussion

Performance of dry direct seeded boro rice

Plant height of DDS *boro* rice was significantly affected by cropping pattern. The highest plant height (95.17 cm) was observed T. *aman* rice - Potato - DDS *boro* rice pattern which was similar with T. *aman* rice - Mustard - DDS *boro* rice, T. *aman* rice - Field pea - DDS *boro* rice, T. *aman* rice - Spinach - DDS *boro* rice, T. *aman* rice - Tomato - DDS *boro* rice and T. *aman* rice - Cabbage - DDS *boro* rice pattern (Table 3). Further, the lowest plant height (82.47cm) was found with T. *aman* rice - Broccoli - DDS *boro* rice pattern which was similar with T. *aman* rice - Garden pea - DDS *boro* rice, T. *aman* rice - French bean - DDS *boro* rice and T. *aman* rice - Field pea - DDS *boro* rice pattern.

Number of total tillers and effective tillers were significantly influenced by cropping pattern (Table 3). The highest number of total tillers $hill^{-1}$ (22.00) was found in T. *aman* rice - Cabbage - DDS *boro* rice pattern which was similar with T. *aman* rice - Potato - DDS *boro* rice, T. *aman* rice - Spinach - DDS *boro* rice and T. *aman* rice - Tomato - DDS *boro* rice and the lowest one (14.67) was obtained in the T. *aman* rice - Field pea - DDS *boro* rice which was similar with T. *aman* rice - French bean - DDS *boro* rice, T. *aman* rice - Mustard - DDS *boro* rice, T. *aman* rice - Garden pea - DDS *boro* rice, T. *aman* rice - Tomato - DDS *boro* rice and T. *aman* rice - Broccoli - DDS *boro* rice pattern. Maximum number of effective tillers $hill^{-1}$ (18.00) was obtained from T. *aman* rice - spinach - DDS *boro* rice pattern which was similar with T. *aman* rice - Mustard - DDS *boro* rice, T. *aman* rice - Potato - DDS *boro* rice, and T. *aman* rice - Cabbage - DDS *boro* rice patterns. The lowest number of effective tillers $hill^{-1}$ (12.33) was found where T. *aman* rice - French bean - DDS *boro* rice pattern (Table 4).

Number of non-effective tillers and panicle length, number of grains $panicle^{-1}$, number of non-effective spikelets, 1000 grains weight, grain yield and straw yield of boro rice did not differ significantly due to cropping pattern (Table 4 and 5). Table 5 showed that the grain yield of boro rice in T. *aman* rice - Spinach - DDS *boro* rice pattern was 5.13 t ha^{-1} and that for T. *aman* rice - Garden pea - DDS *boro* rice pattern was 4.42 t ha^{-1}. The straw yield of boro rice in T. *aman* rice - Mustard - DDS *boro* rice pattern was 6.37 t ha^{-1} that for T. *aman* rice - Broccoli - DDS *boro* rice pattern was 5.35 t ha^{-1}.

Table 4. Effect of *rabi* crops on the plant height, tiller production and panicle length of the succeeding DDS *boro* rice cv. BRRI dhan28 under T. *aman* rice-*rabi* crop-DDS *boro* rice cropping pattern

Rabi crops	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non effective tillers hill^{-1} (no.)	Panicle length (cm)
Mustard	94.03ab	17.00bc	15.33abc	1.67	22.33
Potato	95.17a	19.67ab	17.33ab	2.33	21.73
Field pea	88.87abcd	14.67c	12.33c	2.33	20.77
French bean	84.20cd	15.00c	12.33c	2.67	20.57
Spinach	94.90ab	19.67ab	18.00a	1.67	23.33
Garden pea	88.17bcd	16.33bc	14.00bc	2.33	21.60
Tomato	90.57abc	18.33abc	15.00abc	3.33	21.32
Broccoli	82.47d	15.00c	13.00c	2.00	21.62
Cabbage	94.57ab	22.00a	17.67ab	4.33	23.40
CV (%)	4.43	14.56	14.40	37.04	5.30
Level of significance	**	*	*	ns	ns
SE (±)	2.30	1.47	1.25	0.54	0.67

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letter differ significantly, *= Significant at 5% level of probability, **= Significant at 1% level of probability, ***= Significant at 0.01% level of probability, ns=non significance

Table 5. Effect of *rabi* crops on grain yield and related attributes of succeeding DDS *boro* cv. BRRI dhan28 on T. *aman* rice-*rabi* crop-DDS *boro* rice cropping pattern

Rabi crops	Grains panicle^{-1} (no.)	Sterile spikelets panicle^{-1} (no.)	Weight of 1000 grains (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
Mustard	68.27	21.17	22.00	4.73	6.37
Potato	76.67	22.67	21.10	4.93	6.18
Field pea	65.67	20.67	20.03	4.60	5.53
French bean	61.00	21.33	18.60	4.47	5.40
Spinach	86.67	21.17	22.23	5.13	5.74
Garden pea	64.07	22.83	20.07	4.42	5.57
Tomato	81.17	20.33	20.03	4.53	5.75
Broccoli	56.33	14.36	20.33	4.67	5.35
Cabbage	80.83	24.50	20.90	4.82	5.61
CV (%)	15.34	34.37	6.83	13.94	13.95
Level of significance	ns	ns	ns	ns	ns
SE (±)	6.32	4.17	0.81	0.38	0.46

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letter differ significantly; *=Significant at 5% level of probability, **= Significant at 1% level of probability, ***= Significant at 0.01% level of probability, ns=non significance

In the present study, *boro* rice yield did not vary significantly for different rabi crops included in the T. *aman* rice - *Rabi* crop - DDS *boro* rice patterns. Similar result was observed by Rahman (2021) who found that post-rabi rice yield did not differ due to cultivation of different *rabi* crops under T. *aman* rice - *Rabi* crop - DDS rice patterns at High Barind Tract agro-ecological zone (AEZ-26) of Bangladesh where nine *rabi* crops like mustard, potato, lentil, field pea, radish, cabbage, French bean, carrot and tomato were included and subsequently the rice cv. BRRI dhan28 was sown on 16 March 2018. In the present study, *boro* rice cv. BRRI dhan28 was sown just after harvest of each rabi crop and thus the sowing time ranged from 17 January to 14 March 2019. The farmers of Bangladesh generally grow short duration *rabi* crops like mustard and potato so that *boro* rice can be transplanted without much delay (Rahman, 2021). In connection to the transplanting date of *boro* rice, Islam et al. (2007) reported that BRRI dhan28 gave highest yield for transplanting on 16 January and further delay decreased yield. Similarly, Rahman and Yeasmin (2008) reported that Hybrid rice cv. Jagaroni gave the highest yield when transplanted on 16 January. These reports suggests that *boro* rice should be transplanted as early as possible in the season. As delayed planting causes yield loss of rice varieties, farmers generally avoid long duration *rabi* crops like tomato, field pea, French bean and garden pea in T. *aman* rice - *Rabi* crop - *boro* rice pattern. On the other hand, the present study suggests that inclusion of any long duration *rabi* crop in T. *aman* rice - *Rabi* crop - DDS *boro* rice pattern and sowing of *boro* rice cv. BRRI dhan28 within March would not cause any adverse effect on the yield performance of *boro* rice. Therefore, considering the yield performance of *boro* rice, any rabi crop that allows sowing of *boro* rice within March could be considered for T. *aman* rice - *Rabi* crop - DDS *boro* rice pattern.

Economic performance

Rice equivalent yield (REY) of *rabi* crops and system yield (SY) differed significantly in different cropping

patterns (Table 6). The highest rice equivalent yield (10.37 t ha^{-1}) was observed in cabbage and the lowest rice equivalent yield (4.24 t ha^{-1}) was found in garden pea crop, which was similar with field pea, French bean, and spinach. The highest system yield (19.69 t ha^{-1}) was found in T. *aman* rice - Cabbage - DDS *boro* rice pattern and the lowest system yield (13.17 t ha^{-1}) was found in case of T. *aman* rice - Garden pea - DDS *boro* rice pattern which was similar with T.*aman* rice – Mustard - DDS *boro* rice, T.*aman* rice - Field pea - DDS *boro* rice, T.*aman* rice - French bean - DDS *boro* rice and T.*aman* rice – Spinach -DDS *boro* rice patterns. The highest production cost was required for T. *aman* rice - Potato - DDS *boro* rice pattern (290825 tk ha^{-1}) while the highest gross return (471020 tk ha^{-1}), net return (196195 tk ha^{-1}) and benefit cost ratio (1.71) was found in T.*aman* rice-Cabbage-DDS *boro* rice pattern (Table 7).

Table 6. Rice equivalent yield of rabi crops and system yield of T. *aman* rice - *rabi* crop - DDS *boro* rice cropping patterns

Cropping pattern	Yield (t ha^{-1})			
	Aman rice	REY of *rabi* crops	*Boro* rice	System yield
T. *aman* rice-Mustard-DDS *boro* rice	4.5	5.65cd	4.73	14.88bcd
T. *aman* rice-Potato-DDS *boro* rice	4.5	6.73bc	4.93	16.17b
T. *aman* rice-Field pea-DDS *boro* rice	4.5	4.39e	4.60	13.49d
T. *aman* rice-French bean-DDS *boro* rice	4.5	4.48e	4.47	13.45d
T.*aman* rice -Spinach-DDS *boro* rice	4.5	4.74de	5.13	14.37cd
T.*aman* rice-Garden pea-DDS *boro* rice	4.5	4.24e	4.42	13.17d
T.*aman* rice-Tomato-DDS *boro* rice	4.5	7.27b	4.53	16.30b
T.*aman* rice-Broccoli-DDS *boro* rice	4.5	6.22bc	4.67	15.39bc
T.*aman* rice-Cabbage-DDS *boro* rice	4.5	10.37a	4.82	19.69a
CV (%)	-	10.79	-	6.61
Level of significance	-	***	-	***
SE (±)	-	0.37	-	0.58

In a column, figures with same letter or without letter do not differ significantly, whereas figures with dissimilar letter differ significantly; *=Significant at 5% level of probability, **= Significant at 1% level of probability, ***= Significant at 0.01% level of probability

Table 7. Economic performance of T. *aman* rice - *rabi* crop - DDS *boro* rice cropping patterns

Cropping pattern	Cost of production (tk ha^{-1})	Gross return (tk ha^{-1})	Net return (tk ha^{-1})	BCR
T.*aman*rice-Mustard-DDS *boro*rice	184925	293900	108975	1.59
T.*aman* rice-Potato-DDS *boro*rice	290825	467140	176315	1.61
T.*aman*rice-Field pea-DDS *boro*rice	183025	267660	84635	1.46
T.*aman*rice-French bean-DDS *boro*rice	185725	272460	86735	1.47
T.*aman*rice- Spinach-DDS *boro*rice	168425	268960	100535	1.60
T.*aman*rice -Garden pea-DDS *boro*rice	183025	269160	86135	1.47
T.*aman*rice-Tomato-DDS *boro*rice	194325	318960	124635	1.64
T.*ama*rice-Broccoli-DDS *boro*rice	251325	401010	149685	1.60
T.*aman*rice-Cabbage-DDS *boro*rice	274825	471020	196195	1.71

Production cost includes costs for seed/seedling, manures and fertilizers, herbicide, insecticide and fungicide, labour costs for sowing/transplanting, weeding, inter-cultural operations, harvesting, processing, cleaning and storing. The gross return includes the farm gate sale price for different commodities/produces. The unit sale price per kg in take for mustard, potato, field pea, cauliflower, French bean, lentil, soybean, red amaranth, cabbage and carrot were 50, 10, 10, 50, 55, 65, 60, 20, 10 and 20 tk kg^{-1}, respectively.

In an experiment, Rahman (2018) reported the highest REY for Mustard and lowest for Cabbage in Mymensingh site while potato produced the highest REY and Mustard produced the lowest at Rajshahi site. Rahman (2018) also reported that the highest system yield with T. *aman* rice - Potato - DDS *aus* rice pattern and the lowest with T. *aman* rice – Mustard – DDS *aus* rice in Mymensingh site. In Rajshahi, the highest system yield was recorded in T. *aman* rice - Carrot -DDS *boro* rice and the lowest with T. *aman* rice – Cabbage – DDS boro rice. The present study indicated that the variability in economic performance of different cropping patterns was subjected to the yields of the crops and their market prices. The market prices of vegetables are more variable than the oilseeds and pulses. The demands of vegetables fluctuate depending on the level of production and availability, and therefore the economic profit of a vegetable-based cropping pattern for any geographic location is highly variable although the yield is promising.

Due to introduction of high-yielding short duration rice in the 1970s and increase of irrigated area, *boro* rice replaced most pulses and *rabi* crops (Rahman, 2018). However, crop intensification and/or diversification have now further increased with the inclusion of short duration rapeseed/mustard and potato in between *aman* rice and *boro* rice. The intensification of crop resulted in higher production per unit area per unit time and the cropping pattern containing potato exhibited the highest yield, net return and benefit cost ratio compared to rice-rice and rice-wheat patterns (Biswas, 2015). Based on the economic performance and market situation, T. *aman* rice - Cabbage - DDS boro rice, T. *aman* rice - Tomato - DDS boro rice, T. *aman* rice - Potato - DDS boro rice and T. *aman* rice - Mustard - DDS boro rice patterns could be considered as the promising cropping patterns for Old Brahmaputra Floodplain Agroecological region (AEZ 9) of Bangladesh.

Conclusion

The present study exposed that *Boro* rice yield did not vary significantly in all the nine T.*aman* rice - Rabi crops - DDS *boro* rice patterns although the rice equivalent yield of different *rabi* crops and system yield of the cropping patterns differed significantly. The highest rice equivalent yield (10.37 t ha^{-1}) was found in cabbage and the lowest (4.24 t ha^{-1}) in garden pea. The highest system yield (19.69 t ha^{-1}) was found in T.*aman* rice-cabbage -DDS *boro* rice pattern and the lowest (13.17 t ha^{-1}) in T.*aman* rice - garden pea - DDS *boro* rice pattern. In respect to benefit cost ratio, the highest value (1.71) was found with T.*aman* rice - cabbage crop - DDS *boro* while the lowest (1.46) with T.*aman* rice - field pea - DDS *boro* rice pattern. The present study concludes that *boro* rice could be successfully cultivated in dry direct seeded system after any rabi crops in T.*aman* rice - *Rabi* crops - DDS *boro* rice patterns. Moreover, farmers can adopt T. *aman* rice - Cabbage - DDS *boro* rice, T. *aman* rice - Tomato - DDS *boro* rice, T. *aman* rice - Potato - DDS *boro* rice and T. *aman* rice - Mustard - DDS *boro* rice patterns depending on the demands of the *rabi* crops.

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